Well Passivated a-Si:H Back Contacts for Double-Heterojunction Silicon Solar Cells

Matthew Page, Eugene Iwaniczko, Yueqin Xu,
Qi Wang, Yanfa Yan, Lorenzo Roybal,
Howard Branz, and Tihu Wang

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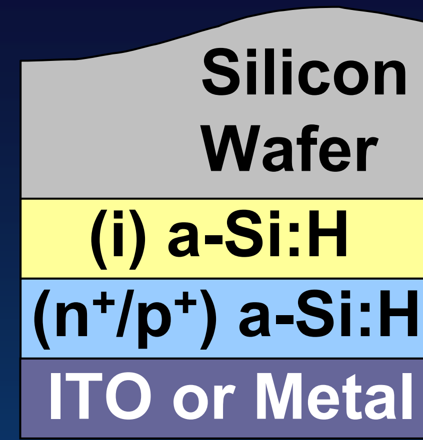
Outline



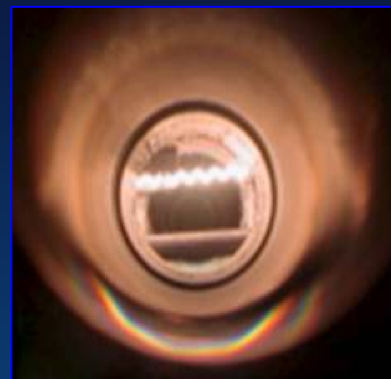
SHJ at Back

- ⇨ Advantage of doing back contact with Silicon Heterojunction (SHJ)
- ⇨ Hot-Wire CVD (HWCVD)
- ⇨ SHJ back-contact better than alloyed/diffused
  - ➢ both n- and p-type wafers
  - ➢ good back-surface-field (BSF)
- ⇨ Critical for good SHJ solar cell fabrication
  - ➢ layer optimization- in brief, here
  - ➢ surface preparation

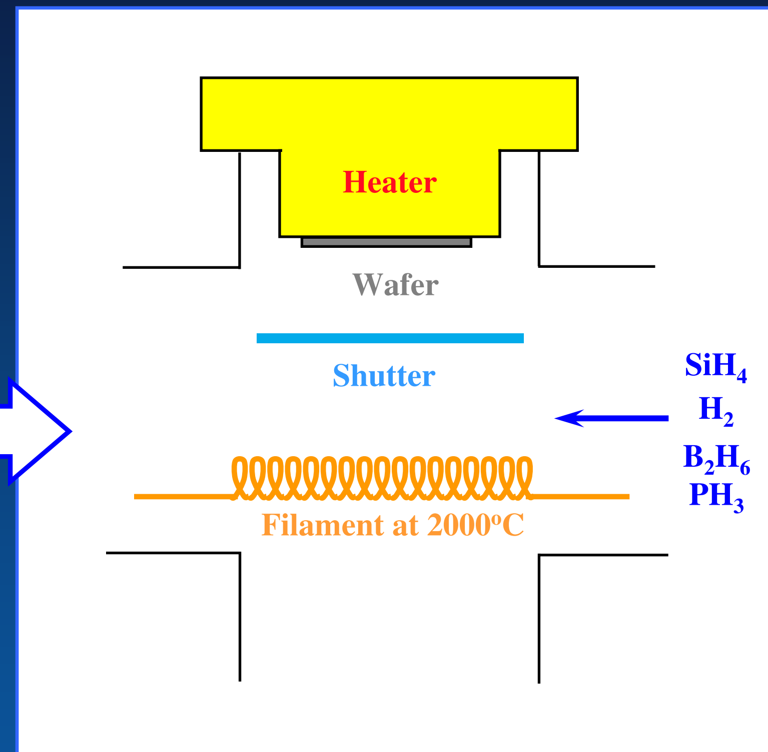
Advantages of a-Si:H/c-Si Heterojunction

- ⇨ Low temperature processing (< 250°C)
  - ➢ preserves high lifetime
  - ➢ compatible with gettering or hydrogenation
  - ➢ prevents bowing (< 200μm wafers)
- ⇨ Excellent passivation on c-Si
  - ➢ LOW minority-carrier recombination velocity
  - ➢ HIGH open-circuit voltage (V_{oc})
- ⇨ a-Si BSF better than alloyed or diffused BSF
  - ➢ both passivation and vertical current conduction
  - ➢ no direct metal/c-Si contact (impurity source)

Advantages of Hot-Wire CVD



- ⇨ HWCVD
  - ➢ simple
  - ➢ scalable
  - ➢ fast deposition
  - ➢ no ion bombardment of c-Si surface



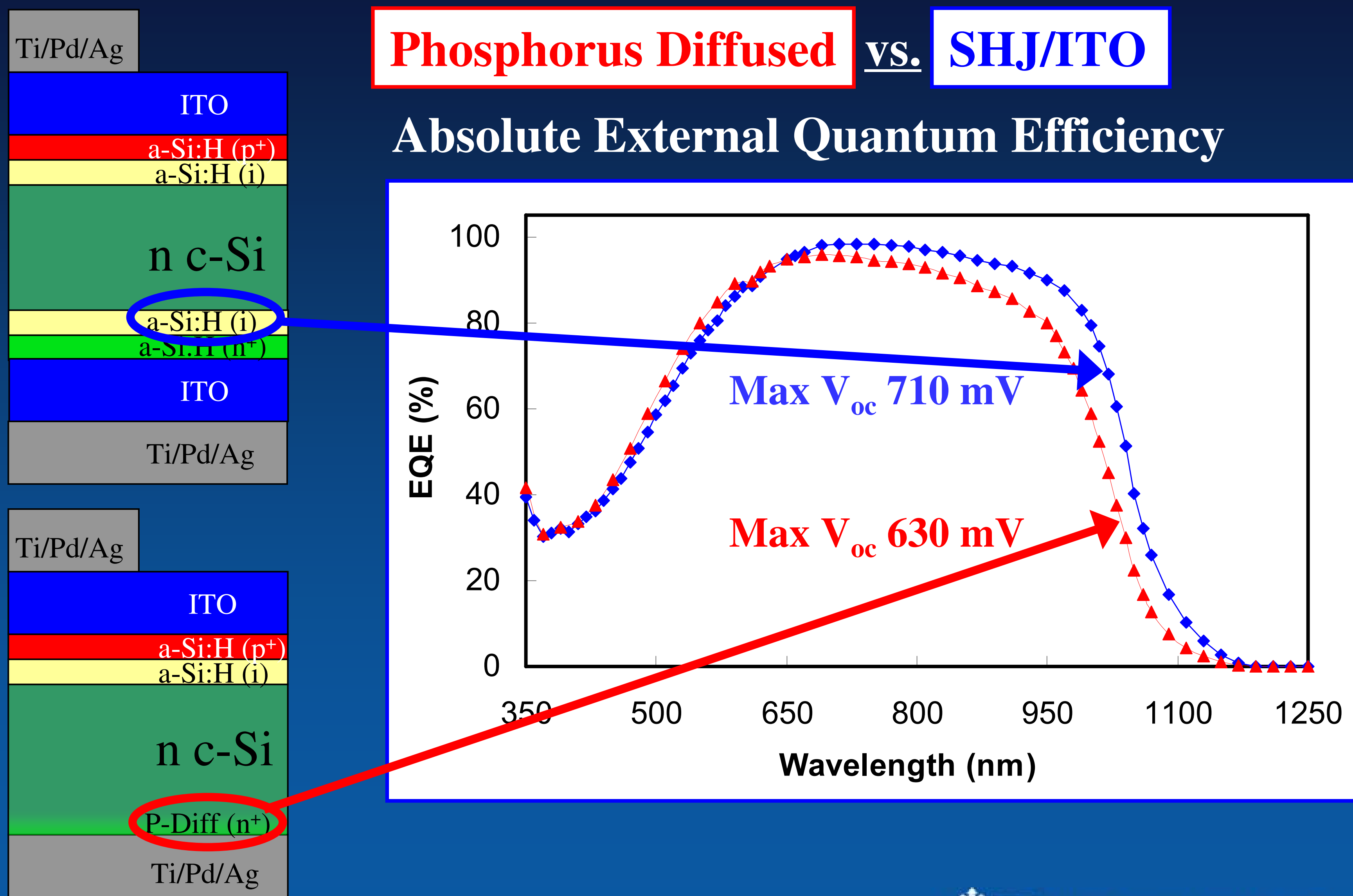
Plasma damage to c-Si a major issue using PECVD

Optimization of SHJ Devices

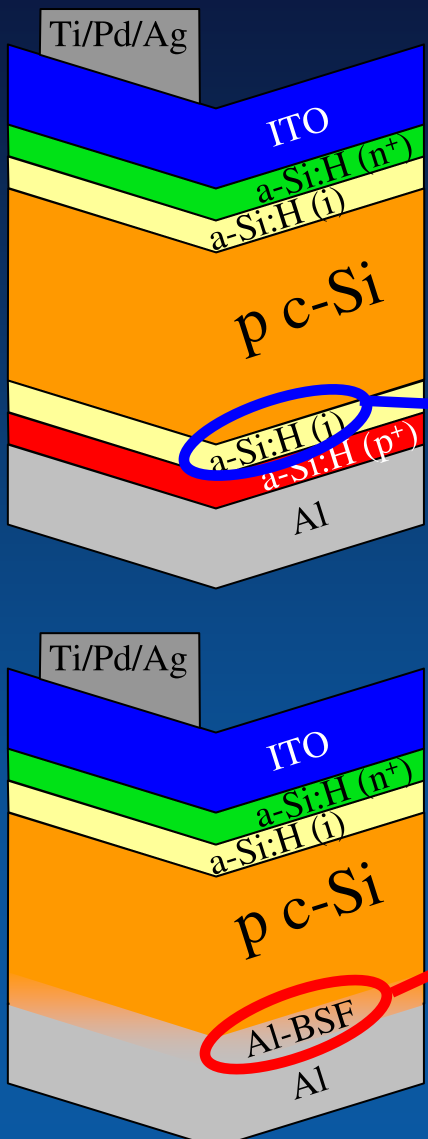
⇨Critical: 1. preparation, 2. deposition

- 1. Very clean SHJ interface preparation (V_{oc})
  - stringent cleaning before a-Si:H deposition
  - junction and contacts close to interface
- 2. High quality intrinsic and doped a-Si:H
  - no epitaxy at interface (V_{oc})
  - low interface defect density intrinsic a-Si:H (V_{oc})
  - high dopant activation in emitter and BSF (V_{oc}/FF)
  - low blue absorption in a-Si:H (J_{sc})
  - good front/back contacts to ITO/metal (FF)

SHJ Back-Contact Passivation (n-type FZ)

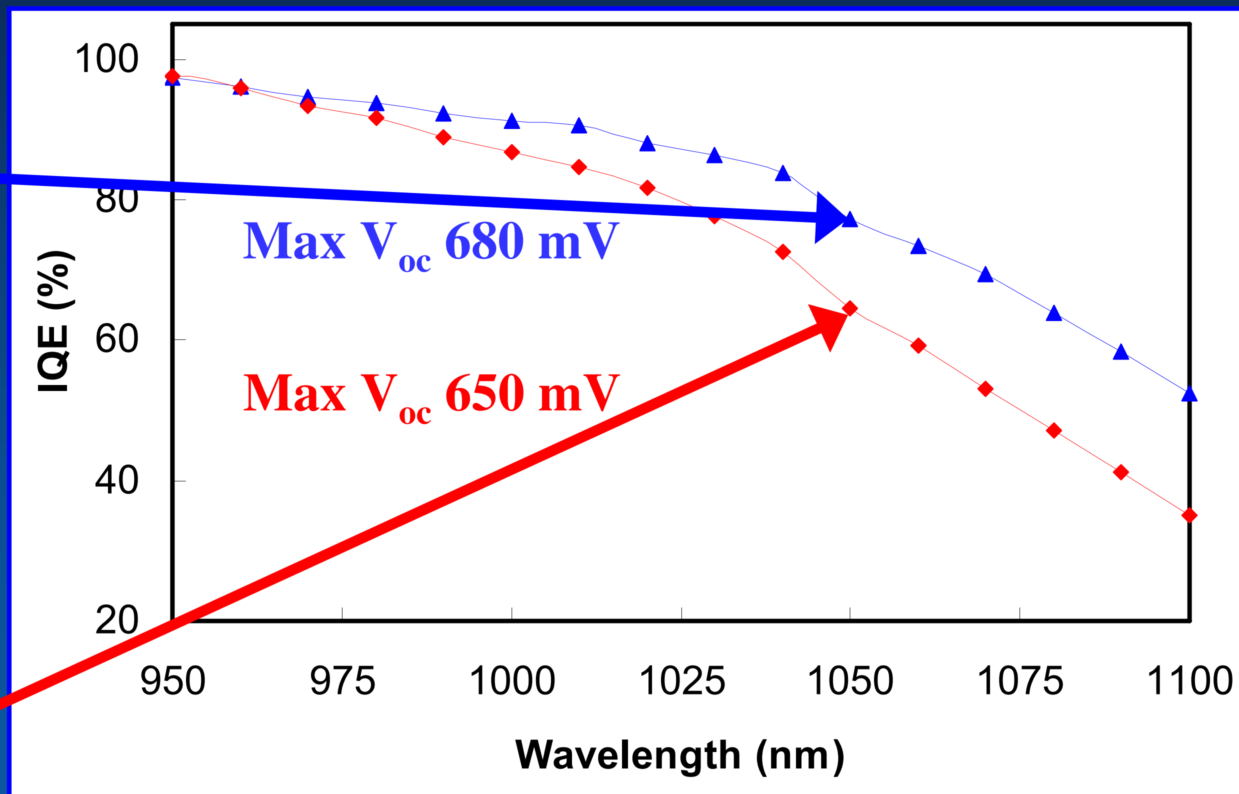


SHJ Back-Contact Passivation (p-type FZ)



Alloyed Al-BSF vs. **SHJ/Al**

Absolute IQE- removing reflectance of front



SHJ Back-Contact is Excellent

⇨ SHJ better than Al-BSF on p-type wafer

- superior back surface passivation
- Fill-Factor greater than 78% achieved
- minority-carrier recombination velocity
  - 15 cm/s for SHJ ⇨ (i/p) a-Si:H/Al

    vs.
  - 1000 cm/s for Al-BSF

⇨ SHJ better than Phosphorous diffused on n-type

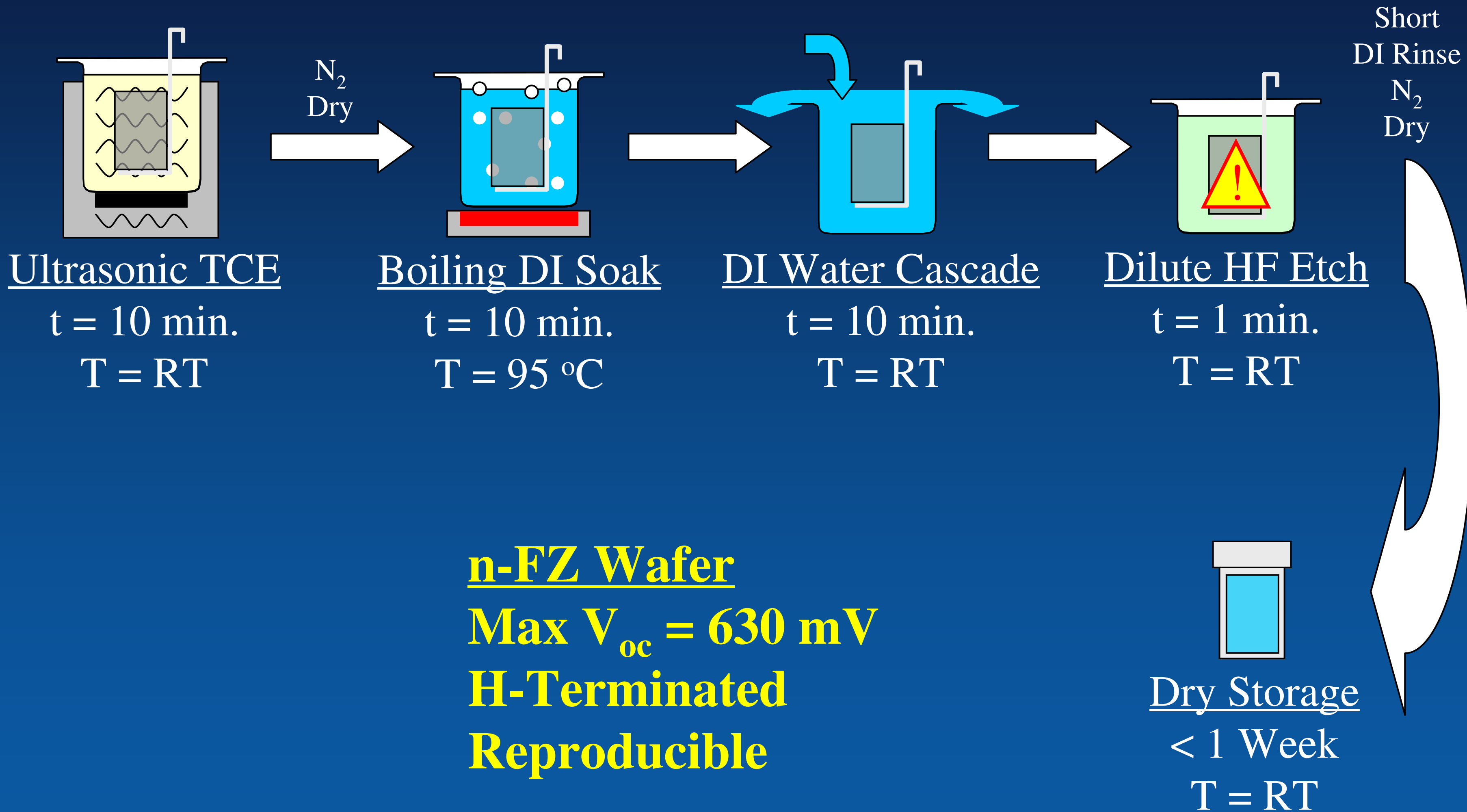
- superior back surface passivation
- Fill-Factor greater than 74% achieved

⇨ SHJ interfaces are more critical than alloyed or diffused junction surfaces

Surface Preparation Important

- ⇨ 4 Generations (GEN-1 through GEN-4)
  - ➢ increasing complexity
  - ➢ developed for SHJ
  - ➢ baseline deposition for each GEN's maximum V_{oc}
- ⇨ Stable oxide and interface
  - ➢ store in clean box
  - ➢ remove impurities trapped in oxide by final HF etch
- ⇨ Protective chemical oxide by RCA-2
  - ➢ 6:1:1 ⇨ H_2O : HCl : H_2O_2
  - ➢ 2.5% HF strip before deposition

GEN-1 Simplest Cleaning Procedure



n-FZ Wafer

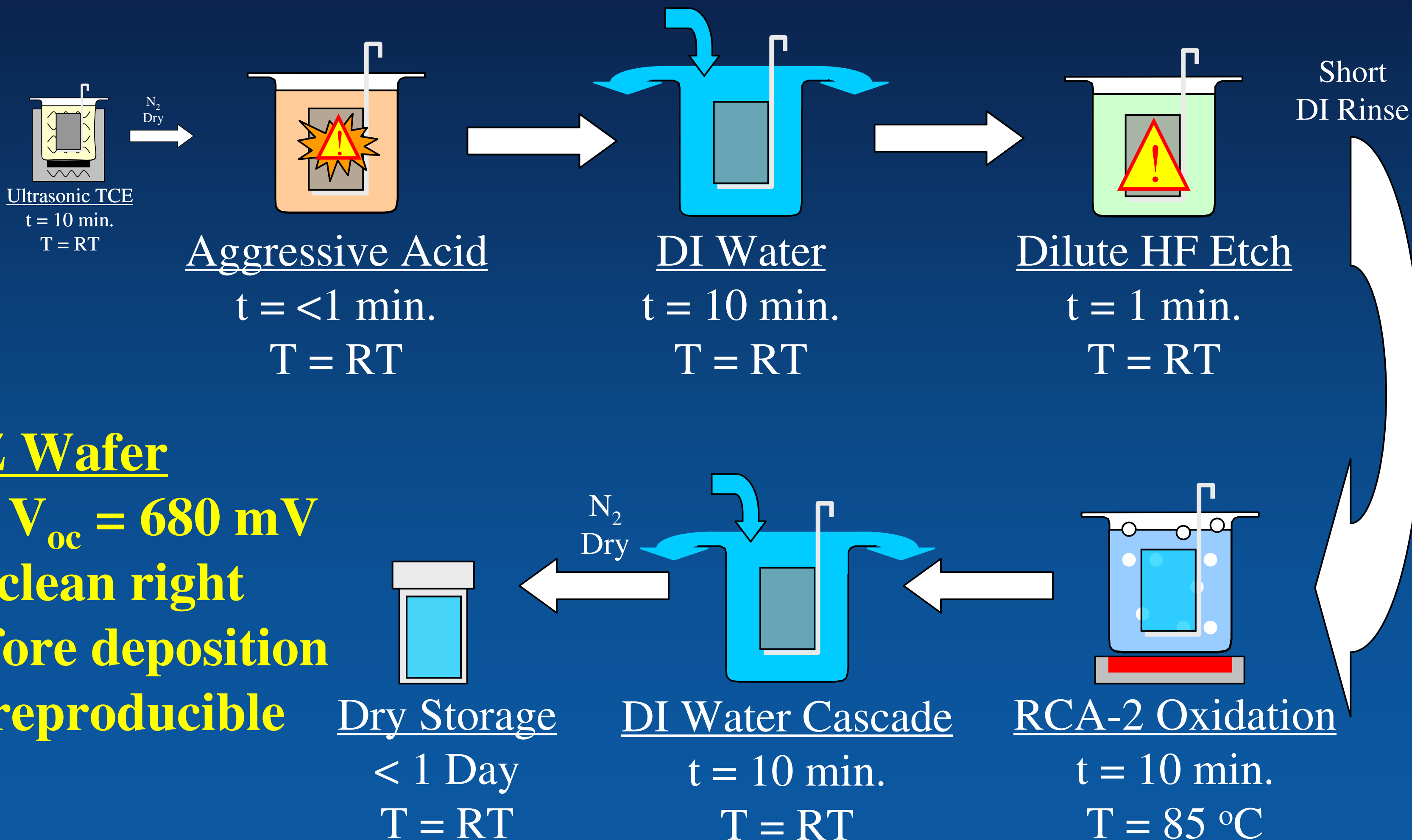
Max V_{oc} = 630 mV

H-Terminated

Reproducible

GEN-2 Aggressive Acid Cleaning

Replaced Boiling DI Water



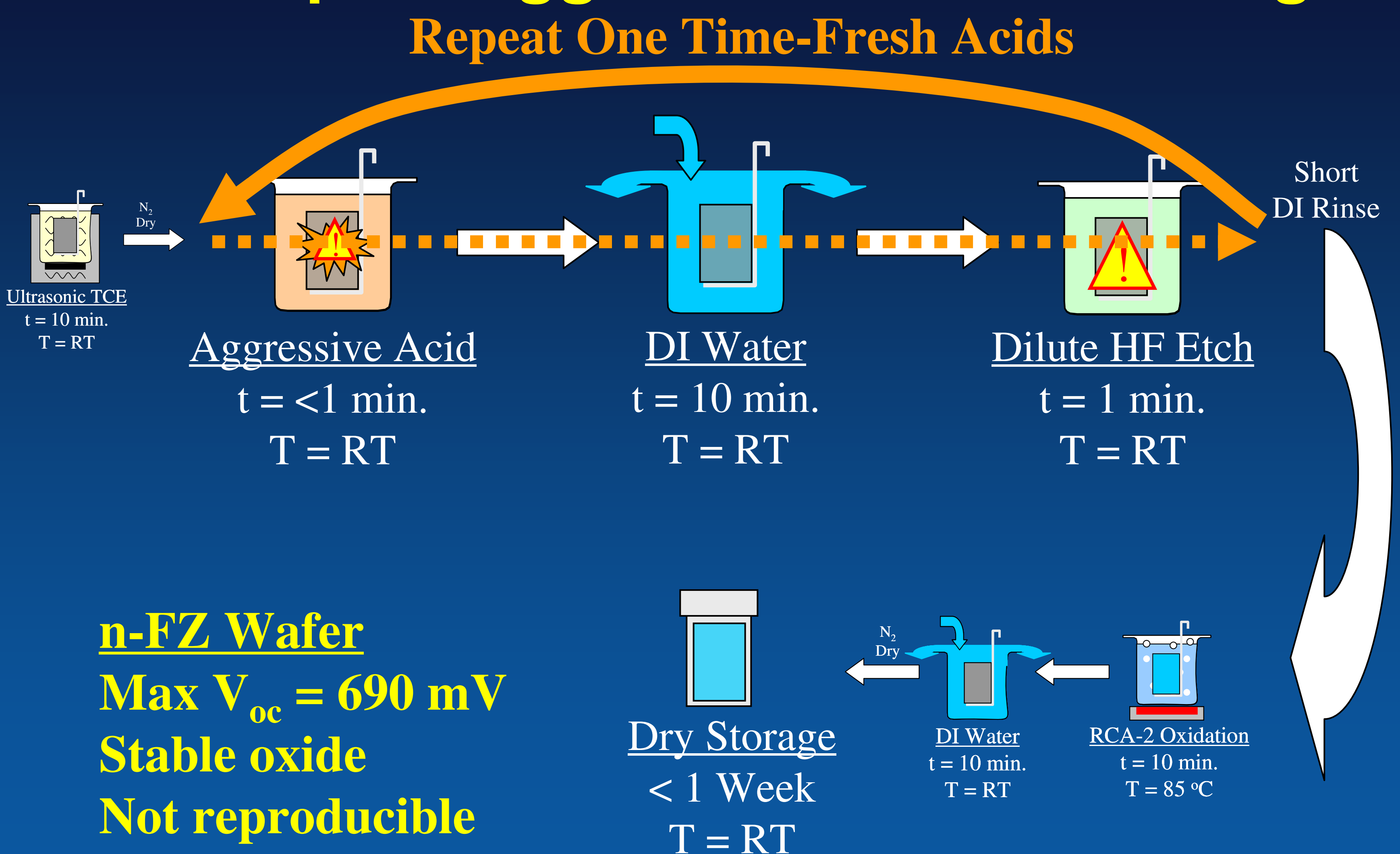
n-FZ Wafer

Max V_{oc} = 680 mV

Full clean right before deposition

Not reproducible

GEN-3 Repeat Aggressive Acid Cleaning



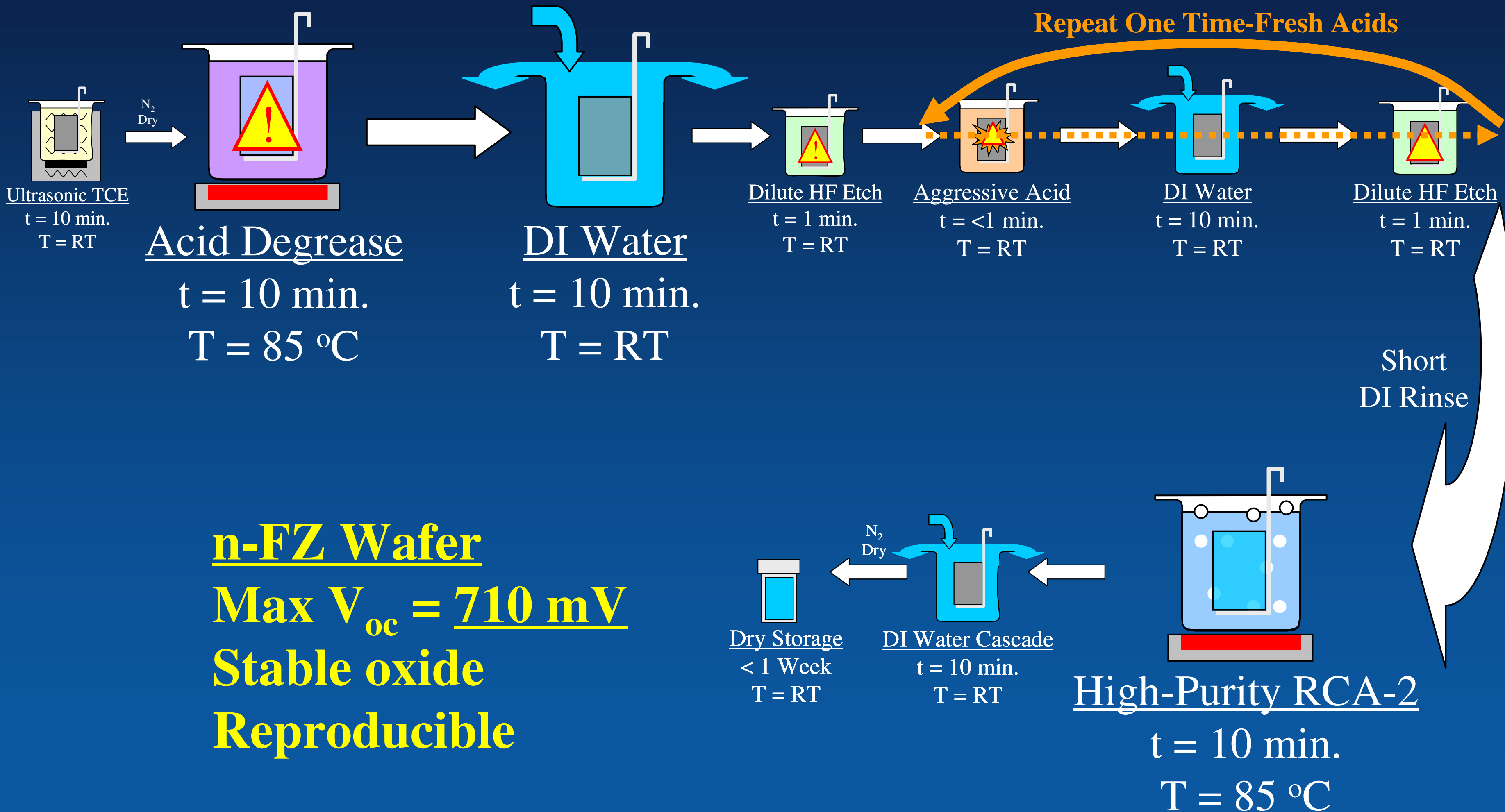
n-FZ Wafer

Max V_{oc} = 690 mV

Stable oxide

Not reproducible

GEN-4 Improved Degrease and Oxide Purity



n-FZ Wafer

Max V_{oc} = 710 mV

Stable oxide

Reproducible

Surface Preparation Summary

GEN-1 Simplest

- H-terminated

GEN-2 Aggressive Acid Cleaning

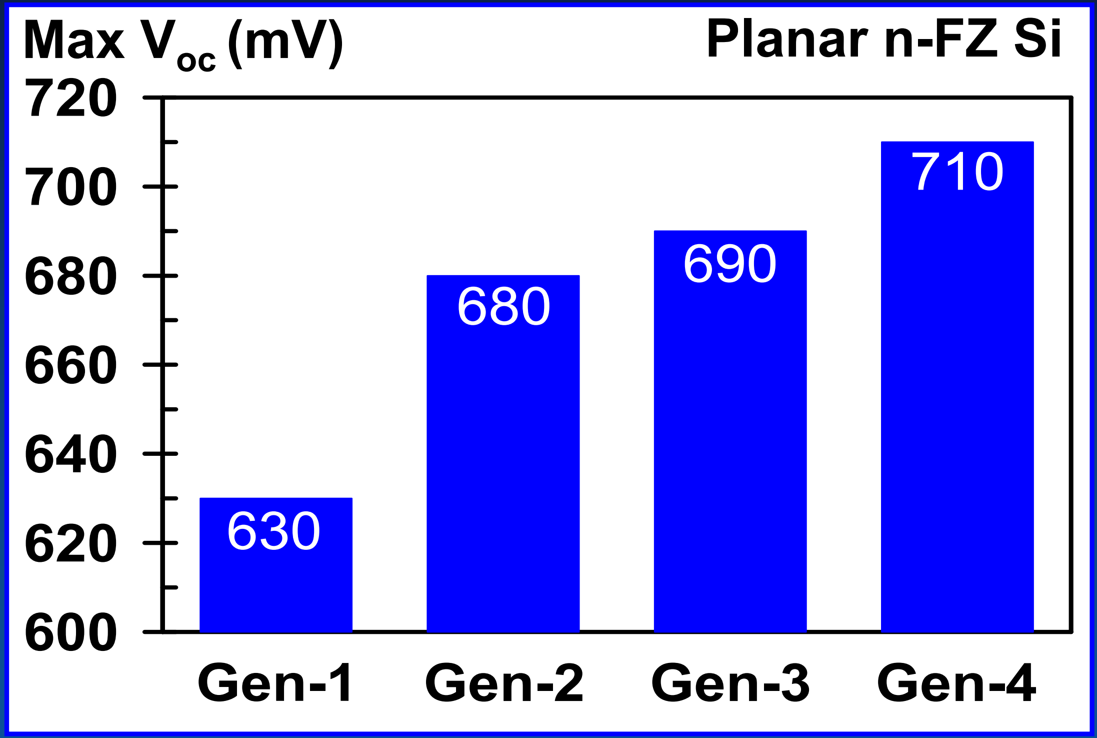
- just before deposition
- not reproducible

GEN-3 Repeated Aggressive Acid

- degrease interaction
- not reproducible

GEN-4 Improved Degrease & Oxide Purity

- reproducible
- stable chemical oxide



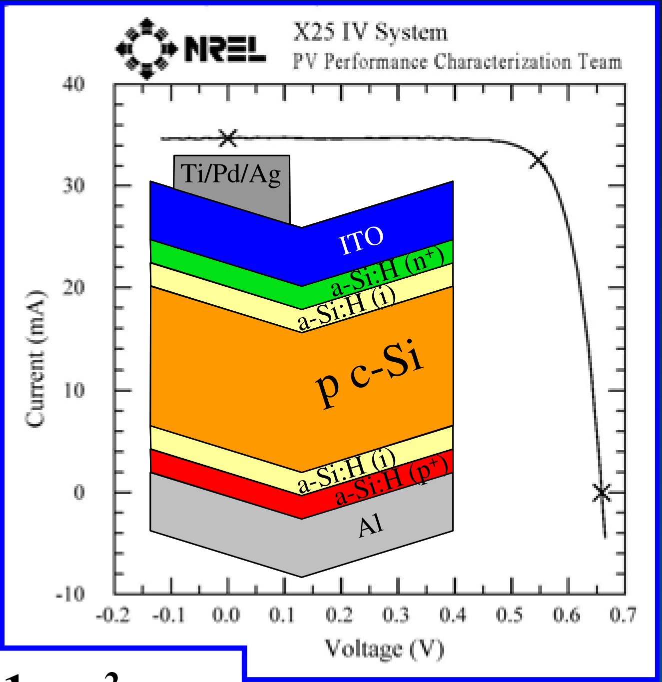
Conclusions

⇨ **SHJ successfully replaced** Al-BSF or P-diffused full area back contacts

⇨ **Surface preparation** and a-Si:H optimization are both critical for device performance

⇨ Confirmed Efficiency

➢ **18.2 %**



AM1.5 1-cm²

V_{oc} = 667 mV

J_{sc} = 35.5 mA/cm²

FF = 76.9 %

η = 18.2 %

ISO-9000 AM1.5 Light I-V measured by Keith Emery & Tom Moriarty

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